Endoscopic Endonasal Approaches to the Medial Intraconal Space: Comparison of Transethmoidal and Prelacrimal Corridors

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Abstract

Background: Endoscopic transethmoidal and prelacrimal approaches can access the medial intraconal space (MIS).

Objective: This study aimed to compare advantages and drawbacks of these two approaches, and to explore their appropriate indications for management of lesions at various locations within the MIS.

Methods: Six injected cadaveric specimens were dissected using an endonasal approach performing a transethmoidal approach on one side and a prelacrimal approach on the contralateral side. The MIS was divided into three *Zones*: *Zone 1* was defined as the area above the superior border of the medial rectus muscle (MRM), *Zone 2* as the area between the MRM and the optic nerve, and *Zone 3* as the area below the inferior border of MRM. The exposure provided by these two approaches to various Zones within the MIS was assessed and compared.

Results: The average height of *Zone 1* to *3* was 10.35 ± 0.45 mm, 11.07 ± 0.59 mm, and 6.53 ± 0.59 mm, respectively. Both approaches provided adequate exposure of *Zone 2* and *3*; however, the prelacrimal approach provided direct exposure of the posterosuperior aspect of *Zone 2* without retraction of MRM. Retraction of MRM was unavoidable using a transethmoidal approach to enhance further exposure. Access to *Zone 1* was adequately achieved through the corridor between superior oblique muscle and MRM via a transethmoidal corridor.

Conclusion: Conceptualizing the MIS into the three aforementioned Zones seems beneficial to select the optimal approach for lesions restricted to each specific Zone. Both the transethmoidal and prelacrimal approaches provide adequate exposure for select lesions in the MIS.

Keywords

medial intraconal space, transethmoidal, prelacrimal, optic nerve, medial rectus muscle, inferior rectus muscle

Introduction

Expanded endonasal approaches (EEA) have been widely applied to access the skull base as well as the craniovertebral junction.[1–4] Furthermore, endonasal approaches to the orbit have been increasingly refined.[5] An EEA to the medial orbit has potential advantages including the preservation of esthetics, direct access, and good post-operative function.[6] Management of lesions within the intraconal space remains a challenge due to the need to use angled lenses, limited maneuverability, lack of precise instrumentation and the potential of injury to the recti muscles and optic nerve.[7,8]

Benign lesions such as hemangioma and schwannoma occasionally arise within the intraconal space.[9–11] In previous studies, a corridor between the medial and inferior

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recti muscles via a transethmoidal approach was used to provide exposure of the inferomedial intraconal space.[12,13] However, the medial rectus muscle is a hurdle for visualization during endoscopic access. Therefore, retraction of the medial rectus muscle is unavoidable to obtain adequate exposure.[14] Moreover, retraction of the medial rectus muscle may damage its blood supply and lead to postoperative dysfunction.[15]

Others have suggested the use of endonasal approaches to the orbit.[16–18] On previous cadaveric studies, partial resection of the orbital floor via a transnasal prelacrimal approach provided a corridor to access the inferior intraconal space,[16,17] and a transethmoidal approach was advocated to access the superomedial intraconal space.[18] Although both the transethmoidal and prelacrimal approaches can access the inferomedial intraconal space, technical nuances, advantages and drawbacks for each approach have not been sufficiently explored. Moreover, whether the prelacrimal approach may be suitable for managing lesions in other regions of the medial intraconal space is undefined.

Therefore, this study aims to compare the advantages and drawbacks of the transethmoidal and prelacrimal approaches for exposing the medial intraconal space, and to explore its indications for the management of lesions locating at varying locations within the medial intraconal space.

Materials and Methods

An endonasal transethmoidal approach (through the middle meatus) and a prelacrimal approach (via the prelacrimal incision by way of orbital floor) to the medial intraconal space were completed in six injected cadaveric specimens (12 sides), performing each approach in contralateral sides of the specimens. Exposure of structures of various regions within the medial intraconal space, as related to each corridor, were explored. The study was conducted at the Anatomy Laboratory Toward Visuospatial Surgical Innovations in Otolaryngology and Neurosurgery (ALT-VISION) at the Wexner Medical Center of The Ohio State University. ALT-VISION and all co-authors were certified by local regulatory agencies pertinent to cadaveric studies.

Visualization was performed using rigid rod-lens endoscopes (4-mm diameter, 18-cm length) with 0°, 30° and 45° lenses (Karl Storz Endoscopy; Karl Storz, Tuttlingen, Germany), coupled to a high-definition camera and video monitor. Both video and standard digital images were recorded during dissections using the AIDA recording system (Karl Storz Endoscopy; Karl Storz, Tuttlingen, Germany).

To contextualize the comparison between the transethmoidal and the prelacrimal approaches, the medial intraconal space was subdivided into three *Zones* by imaginary horizontal lines crossing the superior and inferior borders of the medial rectus muscle (Figure 1). *Zone 1* was defined as the area above the superior border of medial rectus muscle; *Zone 2* was defined as the area between the medial rectus muscle and the optic nerve; *Zone 3* as the area below the inferior border of the medial rectus muscle.

CT scans of six cadaveric heads comprising axial, coronal, and sagittal planes were obtained in Digital Imaging and Communications in Medicine format (DICOM) and imported into Mimics 13.1 (Materialise; Leuven, Belgium) for analysis. Measurements included the height of the maxillary sinus and lamina papyracea, height of *Zone 1* (from superior orbital rim to superior border of medial rectus muscle), *Zone 2* (medial rectus muscle) and *Zone 3* (from lower border of medial rectus muscle to inferior orbital rim), distance between the infraorbital canal and the inferomedial orbital ridge, distances from the lower border of the medial rectus muscle to the medial aspect of the inferior rectus muscle, distance between the medial rectus muscle and the superior rectus muscle. Values were expressed as mean ± standard deviation (SD).

Results

Technical nuances of both the transethmoidal and the prelacrimal approaches have been previously described in detail.[17,18]
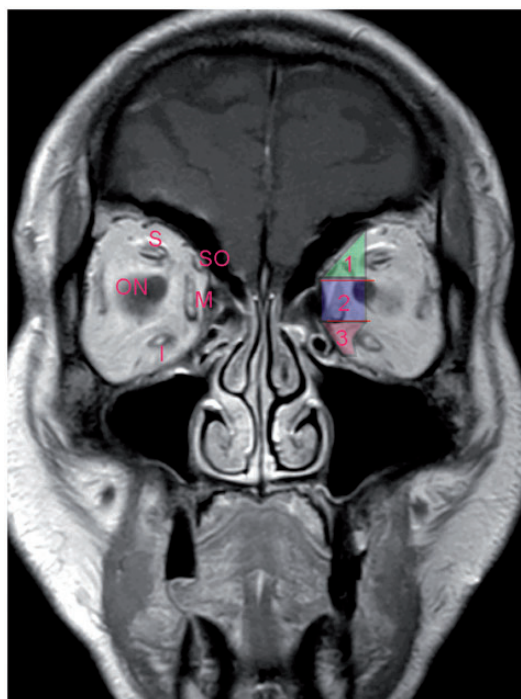

Figure 1. The medial intraconal space is subdivided into 3 Zones. 1, 2, 3 represent *Zone 1* to *Zone 3*. S: superior rectus muscle, I: inferior rectus muscle, SO: superior oblique muscle, ON: optic nerve, M: medial rectus muscle.

Exposure of Medial Intraconal Space via Transethmoidal Approach

Utilizing a transethmoidal approach, the lamina papyracea and the inferomedial bony ridge were removed to expose the periorbita of the medial and inferior orbital walls (Figure 2(A)). The ipsilateral middle turbinate and the posterior segment of nasal septum were dissected to improve maneuverability through both nostrils. The periorbita was incised to expose the fat at the extraconal space of the orbit (Figure 2(B)). *Zone 3* is a narrow space mainly composed of fat and located inferior to the lower border of the medial rectus muscle. After removal of the orbital fat in *Zone 3* (Figure 2(C)), the medial and inferior recti muscles could be inspected (Figure 2(D)).

Orbital fat was further removed to expose the inferomedial muscular trunk of the ophthalmic artery (Figure 3(A)). A transethmoidal approach directly exposes the anteroinferior aspect of *Zone 2* (Figure 3(B)); however, retraction of the medial rectus muscle was needed to expose the posterosuperior aspect of the *Zone 2* (Figure 3(C)).

The corridor between the superior oblique muscle and medial rectus muscle was then explored. After removal of the orbital fat to improve visualization, anatomical structures in *Zone 1* could be exposed, including the anterior ethmoidal artery and nerve, ophthalmic artery, and superior rectus muscle (Figure 4(A)). In order to expose the optic nerve in the lateral aspect of *Zone 1*, downward displacement of the medial rectus muscle was required (Figure 4(B)).

Exposure of Medial Intraconal Space via Transnasal Prelacrimal Approach

A prelacrimal window, allows the inspection of the orbital floor with a 0° scope, identifying the infraorbital nerve, which can be used as a surgical landmark. The posterior two thirds of the orbital floor, medial to the infraorbital nerve were drilled, preserving the bony ridge at the interface of the medial and inferior wall of the orbit (Figure 5(A)). After incising the periosteum, the extraconal fat was removed, allowing the inspection of *Zone 3*, which contains orbital fat and arterial branches from the inferomedial muscular trunk of ophthalmic artery (Figure 5(B)). After careful removal of the orbital fat, the inferior border of the medial rectus muscle could be viewed (Figure 5(C)).

The inferomedial muscular trunk and its branches were protected while exposing the medial rectus muscle and optic nerve in *Zone 2* (Figure 6(A)). The oculomotor nerve branch to the medial rectus muscle was identified
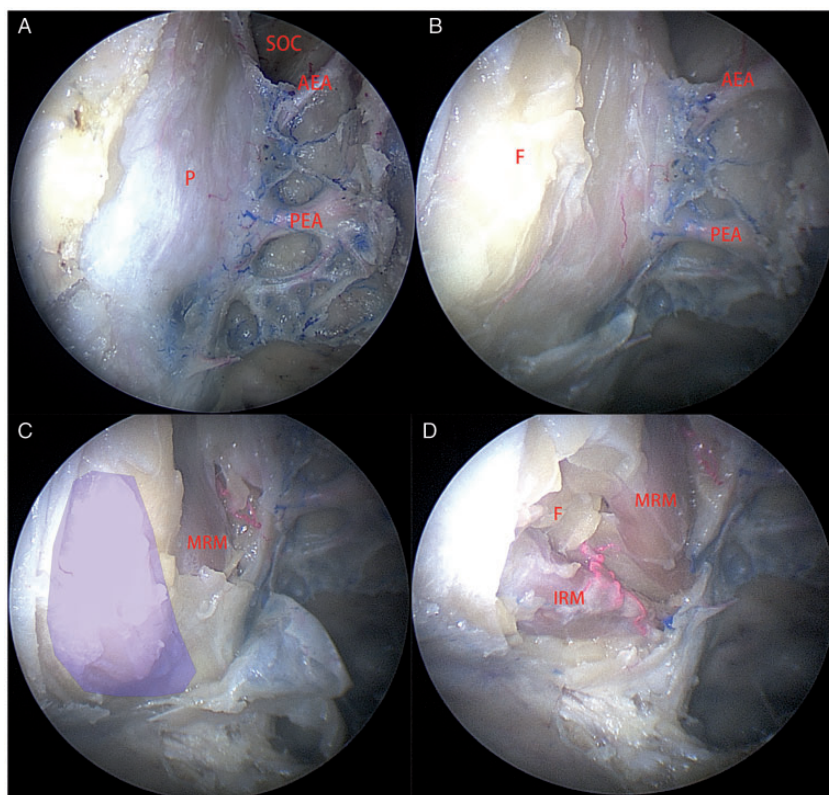

Figure 2. (A) the right periorbita (P); (B) the orbital fat (F); (C) the fat in *Zone 3* (highlighted portion); (D) the medial (MRM) and inferior recti muscles (IRM). Anterior (AEA) and posterior ethmoidal artery (PEA), SOC: supraorbital cell.
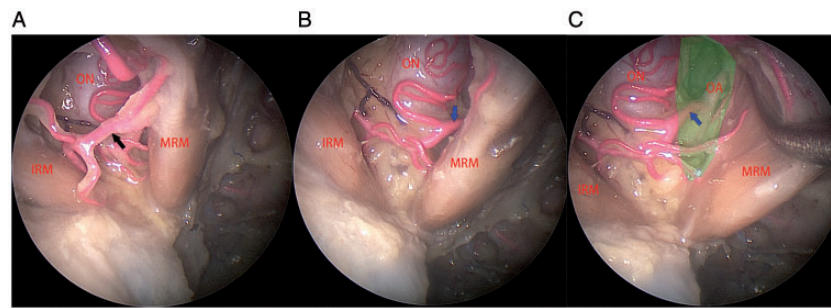
Figure 3. (A) the branches of inferomedial muscular trunk on right side (black arrow); (B) the anteroinferior aspect of *Zone 2*; (C) the posterosuperior aspect of *Zone 2* (highlighted portion) was exposed after retraction of medial rectus muscle (MRM). Blue arrows in B and C represent the inferomedial muscular trunk. OA: ophthalmic artery, ON: optic nerve (For interpretation of the references to colours in this figure legend, refer to the online version of this article).
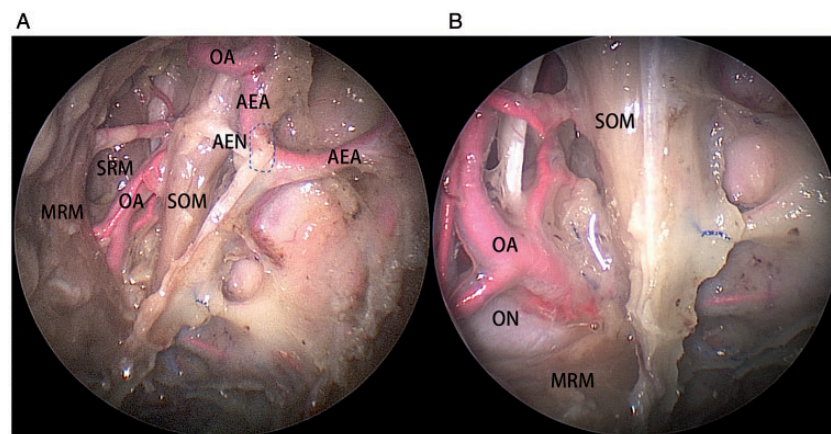

Figure 4. (A) the anterior ethmoidal artery (AEA) and nerve (AEN) on right side transmit the foramina (enclosed dot line); (B) the optic nerve (ON) was exposed after inferiorly retraction of medial rectus muscle (MRM). SOM: superior oblique muscle, SRM: superior rectus muscle.
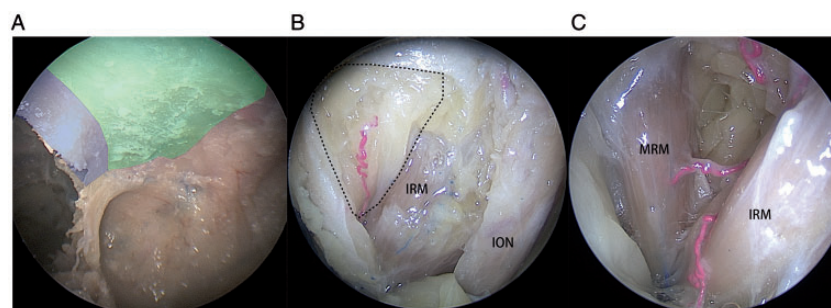

Figure 5. (A) the medial orbital floor on left side was removed to expose the periorbita (green highlighted portion) and the inferomedial bony ridge was preserved (blue highlighted portion); (B) the orbital fat is the main structure of *Zone 3* (enclosed portion); (C) after removal of fat, the medial rectus muscle (MRM) could be viewed. ION: infraorbital nerve. (For interpretation of the references to colours in this figure legend, refer to the online version of this article)

near the superior orbital fissure (Figure 6(B)). On the cadaveric dissections, structures in *Zone 1* including the ophthalmic artery, nasociliary nerve, and superior rectus muscle could be inspected from below but only after removal of the orbital fat in *Zones 2* and *3* (Figure 6(C)).

Measurements of associated indices on CT images (12 sides) are presented in Table 1. Ratio of the height of the maxillary sinus to the height of lamina papyracea was variable with an average value of 1.97 ± 0.38 (range, 1.34–2.61). The average height of *Zone 1* to *Zone 3* was 10.35 ± 0.45 mm, 11.07 ± 0.59 mm and 6.53 ± 0.59 mm,
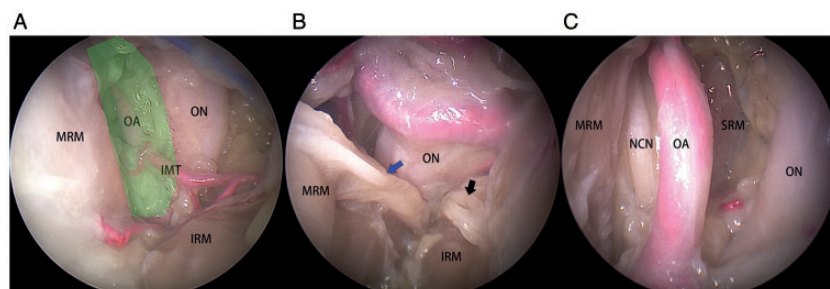
Figure 6. (A) the posterosuperior aspect of *Zone 2* (highlighted portion) on left side was directly accessed via prelacrimal approach; (B) the branches of oculomotor nerve to medial rectus muscle (MRM, blue arrow) and inferior rectus muscle (IRM, black arrow); (C) inspection of the structures of *Zone 1* via prelacrimal approach. IMT: inferomedial muscular trunk, NCN: nasociliary nerve. (For interpretation of the references to colours in this figure legend, refer to the online version of this article)

Table 1. Measurement of Height (mm) of Maxillary Sinus (MS) and Lamina Papyracea (LP), Ratio of Height of MS to LP, Height (mm) of Zone 1 to 3, the Distance (mm) Between the Infraorbital Canal (IOC) and the Inferior Rectus Muscle (IRM), Distance (mm) Between the Medial (MRM) and Inferior Recti Muscles (IRM), Distance (mm) Between MRM and Superior Oblique Muscles (SOM). Ave: average value.

No.	Height of MS	Height of LP	Ratio of MS to LP	Height of Zone 1	Height of Zone 2	Height of Zone 3	IOC and IMR	MRM and IRM	MRM and SOM
1	41.9	16.06	2.61	10.31	10.62	5.41	9.69	7.31	3.95
2	39.7	18.41	2.16	10.64	10.3	5.92	10.12	6.88	4.09
3	37.59	16.99	2.21	9.24	11.16	6.01	10.75	7.15	4.12
4	44.12	18.02	2.45	10.98	10.82	6.29	10.21	7.67	4.08
5	25.07	16.49	1.52	10.1	11.27	7.07	10.81	6.93	3.86
6	23.05	17.16	1.34	10.26	10.43	7.23	10.19	6.93	3.65
7	27.92	15.06	1.85	10.98	11.3	6.12	10.19	6.65	4.19
8	29.81	18.68	1.6	10.35	12.24	7.22	10.41	7.27	3.79
9	31.57	17.4	1.81	10.17	10.85	6.54	10.78	6.98	4.04
10	30.62	16.11	1.9	10.36	10.53	7.18	10.6	6.43	3.72
11	36.49	17.41	2.1	10.32	11.5	6.76	10.74	6.81	4.09
12	40.54	18.92	2.14	10.49	11.83	6.59	10.24	7.19	3.98
Ave	34.03±6.95	17.23±1.17	1.97±0.38	10.35±0.45	11.07±0.59	6.53±0.59	10.39±0.35	7.02±0.33	3.96±0.17

respectively. The average distance from the infraorbital canal to the inferomedial ridge was 10.39 ± 0.35 mm. The average distance between the medial and inferior recti muscles was 7.02 ± 0.33 mm and the average distance between the medial rectus and superior oblique muscles was 3.96 ± 0.17 mm.

Advantages and drawbacks of the transethmoidal and prelacrimal approaches for exposure of medial intraconal space (*Zone 1* to *Zone 3*) are summarized in Table 2.

Discussion

Access to the intraconal space via EEA has evolved significantly over the past decades.[7,12] However, critical anatomic structures such as the optic nerve and extraocular muscles still present a surgical challenge to the intraconal space via EEA.[6] Description of technical nuances and the advantages and drawbacks of the transethmoidal and prelacrimal approaches are helpful to choose the

appropriate corridor for addressing lesions in specific zones within the medial intraconal space.[17,18]

Subdivision of the medial intraconal space into three distinct zones helps selecting the optimal endonasal approach. Although both the transethmoidal approach and the prelacrimal approach can provide good exposure of *Zone 3* (below the lower border of medial rectus muscle, average height 6.53 ± 0.59 mm), lesions arising from the medial intraconal space restricted to *Zone 3* are rare. One potentially significant difference between these two approaches lies in the fact that the prelacrimal approach can preserve the bony ridge at the intersection between the medial and inferior orbital walls, which might be helpful for prevention of enophthalmos.[14] Furthermore, in comparison to the angled visualization and instruments via a transethmoidal approach, the prelacrimal approach could provide direct exposure through the orbital floor,[16] which might improve the ability to avoid damaging adjacent structures (i.e. branches from inferomedial muscular trunk of the ophthalmic artery).

Table 2. Comparison of the Advantages and Disadvantages for Exposure of the Medial Intraconal Space Via Transethmoidal and Prelacrimal Approaches. ON: optic nerve, MRM: medial rectus muscle.

	Advantages	Disadvantages
Transethmoidal approach	1. Direct exposure of Zone 1	1. The ON lies at dorsal aspect when exposed through middle meatus
	2. Better exposure of Zone 3 and anteroinferior aspect of Zone 2	2. Difficult to expose the posterosuperior aspect of Zone 2 without retraction of MRM
	3. Four handed procedure could be obtained	3. Resection of bilateral nasal cavity and posterior septum is required to facilitate 4 handed technique
Prelacrimal approach	1. Not necessary to retract MRM	1. Difficult to expose Zone 1
	2. Better exposure of posterosuperior aspect of Zone 2	2. Difficult for four-hand procedure
	3. Not necessary to incise the contralateral nasal cavity	3. Possible postoperative facial constriction related to the incision

Although the successful extirpation of intraconal lesions (e.g. cavernous hemangioma) via the corridor between the medial and inferior recti muscles has been reported, accessing the region between the medial rectus muscle and optic nerve (*Zone 2*) remains challenging through a transethmoidal approach.[7,19] The superior border of the medial rectus muscle is approximately at the same level as the optic nerve,[20] and the average height of the medial rectus muscle is 11.07 ± 0.59 mm, which may constitute the obstacle for exposing the optic nerve via a transethmoidal approach.[21] Based on this cadaveric study, we found that the anteroinferior aspect of *Zone 2* could be sufficiently exposed via a transethmoidal approach without retraction of the medial rectus muscle. Exposure of the posterosuperior aspect of *Zone 2* close to the superior orbital fissure, however, is restricted by the medial rectus muscle. Although retraction of the medial rectus muscle may help to improve exposure, it may carry the risk of additional damages.[5]

For lesions restricted to the posterosuperior aspect of *Zone 2*, the optic nerve will likely be at the dorsolateral aspect of the tumor when accessed through a transethmoidal approach.[12] Potential to damage the optic nerve will thereby be increased due to the visual obstruction by the tumor.[19] Access to *Zone 2* via a prelacrimal approach employed the same corridor as the transethmoidal approach, the space between the medial and inferior recti muscles (average, 7.02 ± 0.33 mm). The inferior orbit between the infraorbital canal with the inferomedial ridge (average, 10.39 ± 0.35 mm) was removed to facilitate a prelacrimal entry into the inferomedial intraconal space. By comparison with a transethmoidal approach, the medial rectus muscle and the optic nerve are located respectively at the medial and lateral aspects of the tumor when inspected through a prelacrimal approach from below, and retraction of the medial

rectus muscle also is avoided; thus, reducing risk of its potential damage. Moreover, the ratio of the height of the maxillary sinus to the lamina papyracea was variable (range, 1.34 to 2.61). The high ratio proportionally provides more working room for a prelacrimal approach through the maxillary sinus. Conversely, it is a restricting factor to be considered during the corridor selection. Therefore, we favor the prelacrimal approach for managing tumors located at, or extended into, the posterosuperior aspect of *Zone 2*, especially in patients with a well pneumatized maxillary sinus.

For lesions limited to *Zone 1*, a transconjunctival approach or transcranial approach have been considered as the traditional methods for resection.[22–24] Although the measured distance between the medial rectus and superior oblique muscles was 3.96 ± 0.17 mm, we found that *Zone 1* could be adequately exposed by a transethmoidal approach through the gap between these two muscles. However, inferior retraction of the superior border of the medial rectus muscle was often required to enhance the exposure. Moreover, instrument maneuverability during a transethmoidal approach accessing into *Zone 1* is challenging, even when using a binostril technique. Whereas it is reasonable to use a transethmoidal approach for incision and drainage of an abscess or a tumor biopsy, its use for tumor resection or control of a retracted artery, is extremely limited by the poor instrument maneuverability through a narrow space and the risk of damaging the optic nerve.[18] In addition, although structures in *Zone 1* could be exposed through a prelacrimal approach on cadaveric specimens, the orbital fat in *Zone 3* and *Zone 2* needs to be removed or retracted and strict control of the vessels are critical for the exposure, which may be detrimental to ocular function. Therefore, a prelacrimal approach might be indicated as an auxiliary corridor for resection of lesions that originated in *Zone 3* or *2* with superior extension. For lesions

restricted to *Zone 1*; however, the prelacrimal approach is contraindicated.

Preservation of branches from the ophthalmic artery and the protection of nerves within the intraconal space is a requirement to preserve or restore ocular function.[20] Terminal branches of the oculomotor nerve innervating the medial rectus muscle enter the medial border of the muscle. When dissecting tumors in *Zone 2*, these branches should be carefully protected. Moreover, the nasociliary nerve is a thin fiber located at the superomedial intraconal space. During dissections in *Zone 1*, the nasociliary nerve also should be protected to maintain a functional pupil and nasal cavity.

The authors recognize there are significant limitations to this study. It is a pre-clinical cadaveric study, and the application of surgical principles as described for managing lesions at the medial intraconal space needs further clinical validation. Moreover, during the cadaveric dissections, orbital fat was removed to facilitate the exposure of neurovascular structures on cadaveric dissections. However, enophthalmos and bleeding from small arteries within the orbital fat are major concerns during live surgery. Judicious use of a bipolar electrocautery or small cotton compression on live patients may obviate some of these considerations. In addition, one must be aware that the use of 3-4 handed technique, via a prelacrimal approach is significantly restricted. An auxiliary anterior antrostomy may be indicated for management of complex lesions.[25]

Conclusion

Subdivision of the medial intraconal space into three Zones help to select the optimal approach. Both the transethmoidal and prelacrimal approaches provide exposure of *Zones 2 and 3*; however, the prelacrimal approach is more suitable for direct exposure of the posterosuperior aspect of *Zone 2*. For lesions restricted to *Zone 1*, however, the transethmoidal approach seems appropriate.

Authors' Note

This study was presented as a poster at the 30th annual meeting of the North Americas Skull Base Society, February 7–8, 2020; San Antonio, Texas.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: N. London hold stock in Navigen Pharmaceuticals and was a consultant for Cooltech Inc., neither of which are relevant to this manuscript. The other author (s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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